Science, Technology and Society in school science education

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Some key issues in the development of STS education

Historical development of STS education

Timeline

1900	1910	1920	1930	1940	1950	1960	1970	1980	1990	2000
physics and chemistry dominate			rise of biology general science scientific humanists			Nuffield projects	STS SISCON Science in Society SCISP	SATIS Salters projects	Nat. Cm	Cm 2000

STS education attempts to place as much emphasis on technology and society as on science in presenting a coherent view of the relationship between these three strands. The origin of STS education is with scientists and within science education and can be traced back to the 1930s. Scientific humanists such as Bernal, Hogben and Haldane were part of a left-wing movement that strongly promoted scientific knowledge for all, particularly in showing the relevance of science to society. The impact of this radical movement can be seen in contrasting approaches by the Science Masters' Association (SMA) at the beginning and end of the 1930s. In 1930 the SMA discussed the teaching of School Certificate Biology but excluded heredity from the proposed syllabus after extensive debate. Jenkins (1979: 27) suggests *'science masters may have been seeking to dissociate themselves and their Association from the more contentious, even sensational, issues associated with the application of genetic ideas to human society'*. However, by 1938, the SMA had inaugurated 'Science and Citizenship' lectures in response to liberals arguing for citizenship education.

Hogben's (1942) lecture captured the radical arguments for biology as a training for citizenship:

> *Biology can justify its claim to a place in universal instruction if, and only if, it can establish its credentials as a branch of humane scholarship, that it is to say, as an essential part of the intellectual equipment of the individual for the responsibilities of citizenship.*
> (p. 265)

Hogben continued his radical promotion across the sciences in his book *Science for the citizen*. The citizenship emphasis for science education, and biology in particular, came to naught as the traditional features of school science as pure science reasserted themselves in the 1950s.

ABSTRACT

STS education implies that learners consider all three strands – science, technology and society – within a coherent educational experience. This article is not a comprehensive, historical overview of STS education, but rather an attempt to outline some key issues relating to STS education, and, in particular, capture the voice of those involved in major STS projects. For readers who wish to examine more comprehensive accounts, a bibliography is given.

If there is one statement that captures the essence of the article it is this:

'It is the teacher rather than the content that characterises STS education'.

Curriculum development in the 1960s centred around major projects funded by the Nuffield Foundation. Even these ground-breaking projects ignored an STS dimension. If they stressed anything at all about a historical/philosophical/sociological dimension, it was an intellectual history (e.g. developments of cosmological models from Greeks to Newton in Nuffield Physics). Kerr (1966) saw these new courses as teaching science as a process of inquiry and having the potential for furthering a feature of the ASE's 1961 policy statement: *'science should be recognised – and taught – as a major human activity which explores the realm of human experience'*. Yet his comments on the state of science lessons in the 1960s have echoes in perhaps every decade, including the present:

> *Why then do we still read letters in the Press about 'boring science lessons'? Why do some people lay part of the blame for unfilled science places at universities at the feet of science teachers? Why do GCE examination papers, which are supposed to measure all the outcomes of science teaching, still look so familiar – so little changed after several decades?*
> (Kerr, 1966: 301)

STS education could be regarded as one way of dealing with this dissatisfaction.

There were two post-war movements which had great influence in the promotion of STS education. One was started by scientists who felt a sense of responsibility to the public in view of the environmental impact of scientific and technological developments, such as nuclear weapons and pesticides. The second movement was much weaker and was associated with C. P. Snow's 'Two cultures' – breaking down the barriers between arts and science, particularly in post-compulsory education.

Features of the social and political background provided the opportunity in the 1970s for STS education to develop more fully. Public debates about the way science applied to social issues (e.g. eugenics, human impact on the environment, space exploration) perhaps encouraged a timely acceptance that consideration of societal issues had a proper place in science education. The first large-scale STS education project started in Holland in the mid-70s as a result of a government decision to hold a referendum on nuclear power and an eight-year programme of public education to support it.

Major STS developments

Two important UK STS projects, with far-reaching consequences, were also initiated at this time. Both were started by physics teachers committed to extending the post-16 curriculum – an age range where it was easiest for initiatives to be fully developed under teacher control. For John Lewis, the motivation for initiating the Science in Society project came from wishing to extend the range of scientific opportunities in a sixth-form general studies course in a public school. Joan Solomon had similar motivation for producing SISCON-in-schools, but a different clientele – London comprehensive schools. Both developments were keen to promote 'science for citizenship':

> *In traditional science instruction personal opinion is not involved and may be actively avoided. STS instruction, on the other hand, seeks out exchanges between students to help them arrive at personal positions that combine scientific knowledge with moral responsibility.*
> Solomon (1981)

Here I use their comments to tell how these two projects arose.

In 1953, John Lewis, keen to get a little astronomy into the Malvern School science curriculum, attended a DES course on 'General studies in the sixth form' in which astronomy was a component. This course stimulated him to develop experiments on radioactivity for general studies and Nuffield courses, aided by a phial of pure radium inherited from a previous senior science master!:

> *Late in the 1960s, after the initial years dominated by Nuffield, I began to be concerned again by the narrowness of our physics syllabuses and my thoughts turned back to where I began, namely to General Studies in the Sixth Form.*

John developed a general studies course for Malvern, contributing sessions on radioactivity and energy resources and involving heads of many departments in giving stimulating talks. From these early beginnings the Science in Society course evolved, aided, in John's view, by considerations of the purposes of science education proposed by Norman Booth, then Senior Staff Inspector for Science (Figure 1). Science for action and science for citizenship were identified as the guiding principles for the Science in Society project. In 1975, John persuaded companies to give him small sums of money in order to bring interested

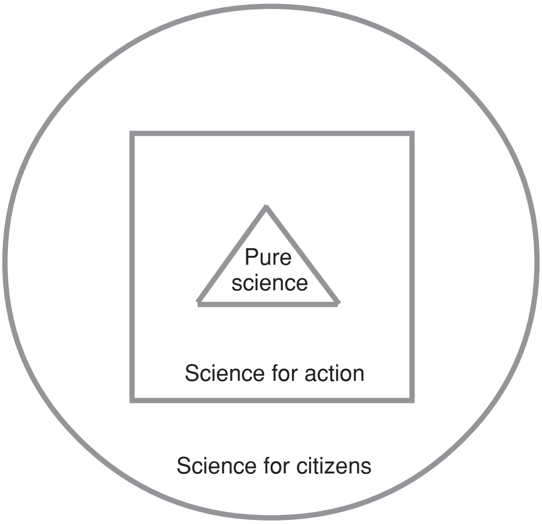

Figure 1 Embedded purposes of science education.

people together for a weekend conference; from this Science in Society was born. After becoming Chairman of ASE for 1977–78, John brought the project under the ASE's wing. A steering committee was established, whose format continued under the committed chairmanship of Ronald Somerville, then a director of Turner and Newall, for all the future SATIS projects.

> *After three years of trials, innumerable meetings in Malvern and immense help from teachers, scientists, industrialists, engineers, the medical profession and other wise people, the project was finally launched at the ASE Annual Meeting in January 1981.*

Joan Solomon traces SISCON-in-schools origins to the post-war nuclear concerns:

> *It is quite difficult now to recreate the anxieties of a whole generation who watched the mushroom cloud develop over Hiroshima at the end of the Second World War. This was one huge part of the incentive for developing STS. The 'atomic scientists' who had worked at Los Alamos set up their famous 'Bulletin', which is still being published, to spread knowledge and discussion of the threat of nuclear war. In England, the same anxiety to teach the public about nuclear fission and radioactivity made a group of young scientists, led by Dr Bill Williams of Leeds University, to rent an empty railway carriage which they furnished with educational materials, mostly written by themselves. They travelled across the country teaching the public so that people could exercise their democratic powers with respect to policy on nuclear warfare and the testing of nuclear bombs. Some years later this group, and others from the polytechnic and university sector, began writing teaching materials which they could exchange and use with their students. By 1970 the group applied for and received enough funds from Leverhulme to start the organisation called Science-In-a-Social-CONtext, or SISCON for short. Many of these SISCON teaching materials, in their bright yellow or red covers are still in existence, covering such subjects as* Limits to growth, The atomic bomb *and* Science, technology and the modern world.
>
> *Each summer SISCON ran a summer school in Harlech College which featured lectures on all the new topics and played host to a number of Dutch colleagues. I and my children attended about 5 of these. In 1973 the Dutch government had decided to hold a referendum on whether to build more nuclear power stations. Realising that the public was largely ignorant of the pros and cons, the Minister for Energy arranged for an eight-year programme of education. In 1976 a joint conference on STS was held in Amsterdam. To this both I and John Lewis were also invited. In 1979, when SISCON was reorganised as STAS, the £200 remaining in the kitty was given to me to fund a SISCON-Schools programme. That paid for the hire of a hall to which secondary science teachers were invited. About 50 of these joined the planning group. Thanks to time off during a strike by school caretakers, and some help in kind from Bristol University, the first series of booklets were written. At first these were aimed at sixth-formers on a general course.*

Both projects have a long legacy and links with ASE. However, critics of Science in Society *'felt that it was too closely identified with the views and values of industry, corporations and professional institutions'* (Hunt, 1994: 70). By 1983 there were two public examination courses at AO-level from these projects, with SISCON-in-schools also contributing a CSE. AS and GCSE syllabuses developed from these, allowing a wide range of students to undertake the courses. At AS they are now superseded by a 'Science for Public Understanding' specification for Curriculum 2000.

In pre-16 education, it has proved more difficult to provide a coherent STS course which does justice to the three essential elements. The political will (or lack of it) for STS education is illustrated by Sir Keith Joseph's response to the new GCSE physics in 1983. As Secretary of State for Education, he rejected the proposals for a physics education which sought to emphasise the wider social and economic implications of the subject. Despite this, *'the early 80s were an optimistic time for curriculum development; the DES document 'Science 5–16' (1985) set out a curriculum model for the emerging GCSE exams and there were National Criteria for the science subjects which included 10–15% social, environmental, economic and technological issues.'* (J. Raffan, pers. comm)

Two parallel initiatives about this time had contrasting approaches. GCSE syllabuses such as 'Salters' Science' were able to take a deliberate social and applications approach across a whole course. Teachers choosing Salters' Science were adopting an 'issues'-based approach to all their GCSE teaching. On the other hand, SATIS materials (Science and Technology in Society) were designed as curriculum enrichment or 'interstitial' activities. SATIS materials arose from 'Science in Society' through projects sponsored by industry and published by the ASE. The SATIS materials encouraged science teachers to extend the range of learning activities and consider applications and social issues in the context of their normal science course:

> *Not only did the SATIS materials introduce STS ideas into science teaching, they advocated innovative ways of delivering the material. Discussions, role plays, etc. had not played a part in many science lessons before. SATIS, with its carefully planned material gave science teachers the confidence to have a go.*
> (A. Fullick, pers. comm.)

As John Holman, director of the first SATIS project in 1984, acknowledges, some of these original SATIS exercises have become institutionalised, even ossified, in current schemes – perhaps a mark of lasting success! This has advantages and disadvantages: STS issues and accompanying teaching strategies are used by large numbers of teachers but the key purpose of examining societal and technological interactions may be diluted. The first SATIS materials, to support GCSE courses, were so successful that finance was forthcoming to support two further projects: SATIS 16–19 under the direction of Andrew Hunt and SATIS 8–14 led by John Stringer. The venture into primary science support was characteristic of the thrust of ASE and science education at the time. Like all STS material, SATIS 8–14 was highly regarded by enthusiasts but did not reach all primary teachers:

> *I was expecting that SATIS 8–14 would be self-promoting, as the secondary projects had been. The difference was that STS education was a statutory requirement at KS4 and above; and seen as an option at KS2 and 3. There wasn't, with the collapse of the advisory teacher system, the information network in primary science education that there was in secondary.*
> (J. Stringer, pers. comm.)

Technological applications were prominent in all SATIS materials, culminating in the project with the least impact – Science with Technology. These materials, designed deliberately to bridge the gap between the science and technology teachers and curricula, focused on applications commonly found in the technology curriculum. They did not have great uptake by schools, despite promotion by both ASE and DATA (Design and Technology Association):

> *The project had great impact but in a very small number of schools and this was largely dependent on key individuals and was probably not sustainable.*
> (J. Sage, pers. comm.)

Integration across disciplines remains difficult:

> *The science and technology curricula remain far too separate.*
> (R. Jackson, pers. comm.)

The nature of STS education

Despite outlining some major STS initiatives, I have not yet discussed what constitutes the aims and content of STS education. An ASE working party in 1984 considered the teaching of science in a social context in a publication, *Rethinking science*, which was designed to enable teachers to reflect on their views and practice (ASE, 1984). The group, containing several key STS advocates, raised three questions for teachers to consider about their future practice (see box opposite).

We might recognise that STS education is characterised by responses at the left-hand end of the continuum. Although a concise definition of STS education may prove to be elusive (Solomon, 1993: 18), the integration of technology and science with society in education for democratic action is an essential feature. Publications to support SATIS 16–

Box

What image of science should school courses give?

Science issues are controversial ↔ science provides right answers

Where should the curriculum be focused?

On pupils and their needs and those of the community ↔ on the teacher's view of the structure of the subject

What kind of social interactions should be included in the science curriculum?

Social issues of science ↔ applications of science ↔ pure science

19 still provide an important contribution to teachers' and students' understanding of these three essential strands (Solomon, 1991).

There have been several efforts to categorise STS education, particularly in relation to general aims for science education. Hargreaves and Hargreaves (1983) matched the aims of the secondary science curriculum against their evaluation of existing STS provision. Table 1 (overleaf) shows their analysis in summary form. While they do not indicate the source or rationale of the aims for the science curriculum, their analysis illustrates the developments which had occurred up to the early 1980s to infuse STS into the pre- and post-16 curriculum. They saw pedagogy as the key to incorporation of STS study into the science curriculum – a theme to which I will return.

Fensham (1988) categories STS materials and courses according to a hierarchical approach of eight types – from use as a motivational tool in learning science through to systematic learning about one or more societal aspects. He sees Science in Society and SISCON as fulfilling the seventh type, in providing the opportunity to give as much weight to the relevant societal knowledge as to the scientific knowledge. Aikenhead (1994) uses a similar typology with the addition of consideration of how students are assessed. This latter point is important where assessment methods are seen as having a significant effect on implementation of courses. For example, SATIS is seen as an example of *'casual infusion of STS content'*, where the balance of assessment in a course is typically 95% science – 5% STS. Only in two UK projects was assessment of STS content significant: SISCON-in-schools – 80% STS (categorised as *'infusion of science into STS content'*); Science in Society – no assessment of pure science (*'STS contents'*) (Aikenhead, 1994).

Solomon (1993: 18) recognises the difficulty in defining STS education but indicates special STS features within science education as including:

- *An understanding of the environmental threats, including global ones, to the quality of life.*
- *The economic and industrial aspects of technology.*
- *Some understanding of the fallible nature of science.*
- *Discussion of personal opinion and values as well as democratic action.*
- *A multi-cultural dimension.*

These themes occur, with different degrees of emphasis, in the aims of STS courses, STS materials, and courses which have an STS element (listed in the bibliography).

A lasting theme in secondary science education has been *'the opportunity to understand something of the scientific background and the implications of economic, social and moral problems which concern us all'* (Nuffield Secondary Science, 1970). Besides appearing prominently in STS courses, it has also featured in the science National Curriculum in various guises, latterly as a requirement that pupils should be taught *'to consider the power and limitations of science in addressing industrial, social and environmental questions, including the kinds of questions science can and cannot answer, uncertainties in scientific knowledge, and the ethical issues involved.'* However, those involved in STS initiatives see STS, particularly the citizenship dimension, marginalised in National Curriculum implementation and assessment.

Table 2 shows the content through which STS themes are developed in different courses. However, the content cannot be divorced from the aims and, particularly, the active learning encouraged.

Table 1 Summary of a typology of STS courses showing compatibility with different aims for, and forms of, the secondary science curriculum (from Hargreaves and Hargreaves, 1983)

Aims for the secondary science curriculum	*Type of STS course*	*Forms of the secondary curriculum where STS occurs*	*Examples of projects and syllabuses*
1.1 To contribute to themes, problems, etc., of relevance to the individual living in society (science for citizenship)	Critical and reflexive	Sixth-form general studies	SISCON-in-schools Schools Council General Studies
		'Integrated science' in which content is negotiable and pedagogy responsive; themes and problems. 11–16	SCISP, Nuffield Secondary Science, Nuffield 13–16 to limited extents
1.2 To show that science can be applied in daily life	Utilitarian	'Integrated science' in which content is negotiable and pedagogy directive; topics. 11–16, lower ability	Schools Council Open Science LAMP project (less academically motivated pupils)
2 To show science as a cultural resource, and as a necessary part of education by presenting science as:	Liberal and humanistic	Subject or 'science' based + STS. 11–18, higher ability	Nuffield single science Nuffield Combined Science A-level Physical Science
2.1 a shaping force (via its history, applications)		Sixth-form general studies	
2.2 a mode of knowledge with rational approach and/or	Emphasis on history and philosophy and/or	As in 2.1	As in 2.1 to limited extent
community activity with social meaning	history and sociology of science	As in 2.1	As in 2.1 to limited extent
2.3 a means of developing personal qualities	Emphasis on need for responsible science	'Pre-science' of primary and lower secondary where content negotiable and pedagogy responsive. 5–13	Schools Council projects: Science 5/13 Progress in Learning Science
3 To enable science as a resource so individuals can satisfy curiosity about the world	Liberal and humanistic	Subject or 'science' based + STS. Teacher and pupils work together on projects as well as formal activities. 11–18	Nuffield single science Nuffield Combined Science A-level Physical Science ILEA Advanced Physics (APPIL)

(continued)

Aims for the secondary science curriculum	*Type of STS course*	*Forms of the secondary curriculum where STS occurs*	*Examples of projects and syllabuses*
4 To provide for the study of science for its own sake (science linked to dominant paradigm(s) and values)	Traditional liberal studies (compensatory, unrelated)	Subject based + STS. Pedagogy directive, relationships hierarchical, content non-negotiable. 11–18, higher ability	Royal Society proposals
5 To provide basis for vocational training by:	Professional responsibility for social aspects	Subject based + STS. Sixth-form general studies. 16–18	Nuffield A-level Chemistry
5.1 showing problem-solving nature of applied science, science as basis for applied science			Science in Society
5.2 allowing science-based generalists to develop	Technocratic	Sixth-form general studies. 16–18	Science in Society

Table 2 Content of some STS examination courses.

Science in Society	*SISCON-in-schools*	*Public Understanding of Science*
Health and medicine	The interaction of man and nature	***Issues in the life sciences***
Population	Logic and certainty as applied to science	Understanding health and disease
Food and agriculture	Technology, invention and industry	Understanding genetics
Facts	Evolution and genetics of the human population	Understanding who we are
Energy	The atomic bomb, the effect of war on science	***Issues in the physical sciences***
Mineral resources	Energy	Understanding our uses of energy resources
Industry in the economy	Health, food and population	Understanding the effects of radiation
Resources of land and water	Space, cosmology, and science fiction	Understanding where we are
Looking to the future		***Ideas about science***
		Data and explanations
		Social influences on science and technology
		Causal links
		Risk and risk assessment
		Decisions about science and technology

Ziman (1994), a proponent of STS in higher education and Chair of the SISCON-in-schools steering committee, identifies seven approaches to STS education: *relevance, vocational, transdisciplinary, historical, philosophical, sociological and problematic*. He suggests that the *problematic* approach of presenting learners with a problem and analysing it from an STS perspective is the most common.

Perhaps, importantly, Solomon and Aikenhead's (1994: 1) reading of Ziman's discussion of STS approaches summarises the most important feature of STS education:

> *It is the teacher rather than the content that characterises STS education.*

With an STS approach, the teacher is presented with both opportunities and problems: a wide range of useful learning activities which allow pupils to share ideas; the controversial and complex STS issues which draw on ideas from a number of disciplines. An STS approach expects pupils to be able to voice their opinions on social issues, while evaluating information about the issue.

Science in Society and SISCON-in-schools focused on major themes through readers, decision-making exercises and (with Science in Society) audio-tapes. Both projects had detailed teachers' guides which outlined approaches, SISCON showing how teachers had tackled this innovation through using group discussion, magazines, films and television, simulations and games. This variety of activity was continued in the SATIS materials, with 'There isn't always a right answer' being a guiding principle of the activities.

Types of assessment

A reflection of the outcomes expected from STS education can be gleaned from assessment instruments in STS courses. Coursework is an important feature of STS assessment in exam courses, stemming from SISCON-in-schools and Science in Society. Typically 20–30% of the total marks are given to a written project and oral work – as contributions to group discussion. The written project is on an STS theme of the student's choosing with credit given for research initiative, content, presentation of findings and evaluation.

Questions on written papers normally expect students to interpret a passage in the light of their experience of the ideas on the course, although the early exam papers provided more open-ended essay-type questions (see below). This reflects the trend towards structured short-answer questions seen in other science examinations over the years.

> *In August 1979 there is to be a United Nations Conference on 'Science and Technology for Development'. a) Say what you understand by the word 'development'. b) Suppose you decided to submit a paper on 'The role of science and technology in development', what points would you make?*
> (1979 AO-level Science in Society)

> *'Study of the heavens has always involved the hopes and religious beliefs of society every bit as much as its scientific knowledge.' Use your knowledge of either primitive cosmology or the conflict between Galileo and the Church to provide examples to support this statement.*
> (1982 AO-level SISCON (JMB) exam)

> *There has been much talk for some time of the 'Energy Crisis'. Describe in your own words what you think the Energy Crisis is and how it might affect lives.*
> (1982 CSE Mode 3 SISCON exam)

Teachers as curriculum developers

Over the years many science teachers have been involved in the development and trialling of STS materials. In explaining their involvement, several have highlighted how they always had an interest in putting science in a societal and technological context. The particular STS project allowed them to further their practice with support and encouragement:

> *This was a very enriching time for me professionally as I returned to school full of ideas for introducing more context into physics and science teaching.*
> (M. Whitehouse, pers. comm.)

In researching for this article, I found a number of characteristics of teacher involvement in STS initiatives very striking.

STS projects are likely:

- to be led by committed individuals with vision and enthusiasm;
- to encourage a network (local, regional and, through ASE, national) of enthusiastic science teachers, who retain an optimism for STS as a major focus for science education;

- to have materials which are developed and trialled by practising teachers and are often developed in association with experts in industry and business;
- to be financed by charitable trusts or industry. Most of the STS initiatives discussed in this article relied heavily on the financial support and goodwill of sponsors.

These characteristics may echo features of other curriculum development projects. However, as long as STS is not the main focus for science education programmes, it may rely on such activities and enthusiasts for its future survival.

The future of STS

The late twentieth century has seen further discussion of the science curriculum at a time when the National Curriculum was undergoing review (Millar and Osborne, 1998). Millar (1996) argues for a science curriculum for public understanding based on: identification of a small number of key models as the core content; a more technological emphasis; case studies of the historical development of ideas, of actual scientific work and of disputes about applications. While these proposals are not totally coincident with STS education as characterised above, the 'science for citizenship' dimension is prominent.

The key questions which underpin STS education continue to provide a debating ground for the future of science education:

- What is science?
- What is technology?
- How does society decide?

These remain fundamental and difficult questions which are worthy of revisiting, along with pedagogical practices, in preparing pupils for citizenship in a global society.

Will future STS efforts see any substantial change to existing practices? Will the pedagogical and assessment strategies and teacher training necessary for dealing with the integration of science, technology and society be given due attention? Will STS education continue to be marginal rather than central? One STS advocate argues:

> *I am still convinced that the main thrust for STS education is not through specialist options but to insist upon a substantial weighting in mainstream specifications and more robust attempts to assess it in well-designed examination questions.* (J. Raffan, pers. comm.)

Will the educational, political and social will follow this path? From an STS point of view some optimistic elements can be seen: citizenship now emerging strongly across the curriculum; international efforts to assess scientific literacy (PISA, 2000). However, considerable challenges for the twenty-first century remain, not least those of the impact of assessment on the curriculum as taught, the needs and development of science teachers and integration of STS across the curriculum. How much change will be seen in the next 100 years?

Acknowledgements

Many people have contributed over the years to STS materials and projects. A quick look at STS project teachers' guides indicates the range and commitment of individuals. I have not attempted to make systematic contact with all these people. However, I am indebted to the detailed comments of the following in response to my requests for information on their involvement in STS projects: Ann Fullick, John Holman, Andrew Hunt, Roland Jackson, John Lewis, John Raffan, Jim Sage, Joan Solomon, John Stringer, Mary Whitehouse. Undated quotes are from their comments. Any responsibility for (mis)interpretation is mine. In addition, I would like to acknowledge the advice, information and comments from Joan Solomon that have been used to revise an earlier draft of this article.

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SATIS 8–14 *Boxes 1–3* (1992)

Science with Technology (1995) 5 extended units; 7 focused units; *Science with Technology Toolkit.*

Syllabuses

Salters' Science GCSE syllabus, MEG 1996.

Science and Technology in Society AS syllabus, OCSEB/NEAB 1996 and 1997.

Science, Technology and Society GCSE syllabus, MEG 1998.

Science, Technology and Society GCSE syllabus, NEAB 1998.

Science for Public Understanding AS specification, AQA 2000.

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